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PHASES OF ADOLESCENT DEVELOPMENT IN GIRLS*

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DISCUSSION *by H. Lisser, M. D., San Francisco; William Anthony Reilly, M. D., San Francisco; H. E. Thelander, M. D., San Francisco.*

THE present report is concerned with the significance of individual differences in body build as a factor in growth and development. Physical, physiological, and observational records of a group of about one hundred girls furnish the basis for the study. The physical data include anthropometric measurements, clinical physical examinations, observations, x-rays, and serial photographs. The children studied here, as a part of the seven-year study of adolescence being carried on at the Institute of Child Welfare, have been examined each six months, beginning at the age of approximately ten years.

The longitudinal method has been used, the development of each child being followed over a period of several years. This has required the maintenance of cumulative records, and makes possible both the consideration of status at successive age levels, and of cross-sectional as well as longitudinal relationships. Interrelationships between several of the different types of data have been traced.

As a technique for exploration of relationships, a group of girls of extremely slender build have been contrasted with another group of girls characterized by extremely broad body build. These two samplings at the extremes of the normal distribution were selected [1] on the basis of an index of body build, consisting of bi-iliac diameter divided by standing height. Data from the two contrasted groups reveal certain significant relationships between the anatomic measures and physiological variables. The two groups of children have characteristically different growth patterns. The findings suggest that, in studies dealing with growth and development, proper interpretation of the data from a random sample requires the recognition and measurement of individual differences, and proper allowance for certain individual patterns of growth.

* From Stanford University and Institute of Child Welfare, University of California.
Read before the Pediatric Section of the California Medical Association at the sixty-sixth annual session, Del Monte, May 2-6, 1937.

THE ASSESSMENT OF GROWTH

In the measurement of growth, it is necessary to recognize a number of variables in addition to actual stature or size. The important thing in growth is the maintenance of an adequate rate of progress, normal for the individual, rather than the attainment of uniform size for all individuals at a given age. It is necessary to recognize big-boned family lines and small-boned family lines, as well as the stunting effects of certain serious illnesses. In the present study, interviews with the parents were held in order to gather information on family heredity, as a help in recognizing growth patterns.

The use of x-rays in study of physical growth is comparatively recent, but various methods of measuring the extent of ossification have been devised in order to assess development.[2-4] Appearance of centers of ossification, stages of fusion of epiphyses with their diaphyses, total carpal area, and diameters of the carpus have all been used by various authors to estimate anatomic age. Todd [5,6] used centers of ossification in shoulder, knee, and foot, to supplement hand and wrist in order to judge skeletal development. Both Rotch [7] and Stevenson [8] have demonstrated the wrist to be an adequate indicator of the ossification in all the epiphyses in the skeleton. Since this area can be x-rayed with the least expense or inconvenience of any part of the body, it is the one now generally used. The wrist is a satisfactory area in which to study ossification, because, while cartilaginous at birth, it has eight bones at maturity, and hence in the transition it exhibits many stages of development.

Centers of ossification appear in definite sequence, and failure to appear when they should indicates an illness at or near the time of appearance. The ends of the long bones, particularly the tibia, and the radius, are marked with rings which show pauses in the bone growth following severe measles, scarlet fever, or other long-continued fever. Children from slum districts show more developmental scars of this type than do those in better homes.

The various retardations in development due to illness may be responsible for some of the irregularities in growth noted during the adolescent period. These irregularities are no doubt related to the awkward phases of imbalance between bone growth, muscle growth, and endocrine or organ maturity. The awkward stage of stress and strain is more marked in early adolescence, and disappears as irregularities in growth diminish.

X-rays show no distinction in amount of ossification in boys and girls up to five years. By age ten, the girls show quite a developmental spurt, and the girls finally attain their mature form before boys. The female skeleton reaches approximately its adult level at about fifteen years, when the epiphyses close and there is no further growth in stature. In boys, adult stature and skeletal weight are not attained until age eighteen.

We have used the appearance and growth of centers of ossification in bones, to measure physical

TABLE 1.—*Means and Standard Deviations of Distributions of Anthropometric Measurements of Ninety-three Twelve-Year-Old Girls*

	Mean	Standard Deviations
Chronological age (years)	12.2	.13
Weight (in kilograms)	43.0	84.4
Height*	1,509.1	70.3
Sitting height	787.4	37.5
Stem length	772.8	38.5
Bi-acromial diameter	322.5	18.0
Bi-iliac diameter	244.5	16.5
Bitrochanteric diameter	278.3	22.2
Chest breadth	234.6	16.9
Chest depth	158.7	16.4
Neck circumference	289.2	15.8
Chest circumference at nipple	755.3	73.0
Chest circumference submammary	698.5	55.2
Arm circumference	219.0	22.0
Thigh circumference	457.7	51.6
Leg circumference	307.0	23.9
Breadth and length	162.3	7.8
Per cent breadth and length	.33	4.7

* Measures 3 to 16, inclusive, are recorded in millimeters.

TABLE 2.—*Anthropometric Measurements of Nine Girls, Classified as Linear*, Measured at Ages Between 12 and 12.4 Years*

Variable	Mean	Range of Scores	
		Highest	Lowest
Chronological age	12.1	12.4	12
Weight	36.2	45.3	25.3
Height	1,493.5	1,617	1,389
Sitting height	763.5	839	704
Stem length	752.4	815	698
Bi-acromial diameter	313.3	338	281
Bi-iliac diameter	221.1	249	196
Bitrochanter	256.3	289	231
Chest breadth	215.5	233	200
Chest depth	152	172	134
Neck circumference	273	293	250
Chest circumference at nipple	681.8	720	590
Chest circumference submammary	648.5	680	582
Arm circumference	199.7	232	165
Thigh circumference	399.6	487	243
Leg circumference	288.2	314	246
Breadth and length	148.3	155	141
Per cent breadth and length	- 7.5	- 12.2	- 4.3

* Girls who were 1½ standard deviations narrower than the average were classified as belonging in the extreme "Linear" group. These data are to be compared with Table 3, which gives similar measurements for the nine girls classified as "Lateral."
Body weight is recorded in kilograms; other anthropometric measurements are recorded in millimeters.

development, following the technique described by Dr. T. Wingate Todd, who has studied the problem extensively over a period of years.

In this series of data, a skeletal age difference of three and one-half years is the maximal difference between the most accelerated and the most retarded bone-ages at a given chronological age. This indicates the great extent of individual differences in skeletal development at a given chronological age. A child whose skeletal ossification exceeded or lagged behind the mean of her age-sex group by more than nine months (three times the standard deviation) was classed as of accelerated or retarded development, respectively. Children were classified as average, who did not exhibit as much as nine months' acceleration or retardation.

THE MEASUREMENT OF BODY BUILD

As a part of the measurement procedure every six months, a series of anthropometric measurements was taken. (See Table 1). These included measures of both length and width, and provided the basic data for determination of body build, the

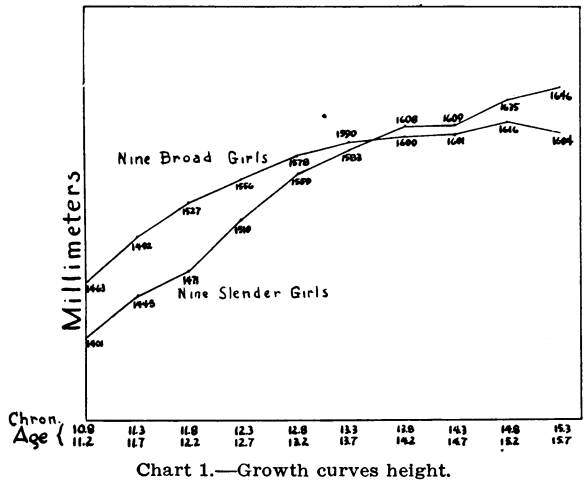

Chart 1.—Growth curves height.

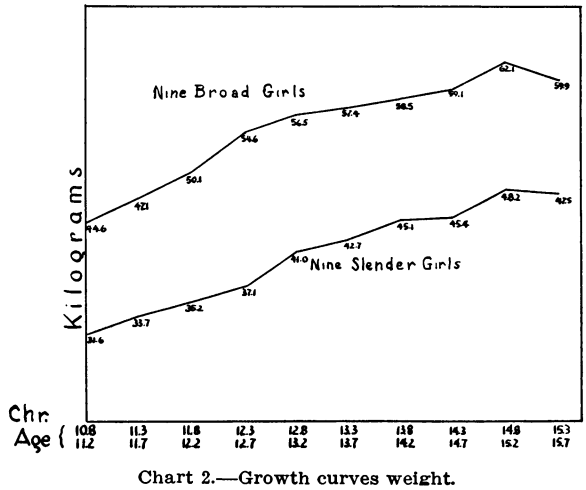

Chart 2.—Growth curves weight.

TABLE 3.—*Anthropometric Measurements of Nine Girls, Classified as Lateral*, Measured at Ages Between 11.9 and 12.4 Years*

Variable	Mean	Range of Scores	
		Highest	Lowest
Chronological age	12.2	12.4	11.9
Weight (kilograms)	51.8	63	42.3
Height (millimeters)	1,537.1	1,634	1,435
Sitting height	807.8	864	750
Stem length	792.7	850	719
Bi-acromial diameter	335.1	370	304
Bi-iliac diameter	266.7	280	252
Bitrochanter	298.8	318	264
Chest breadth	254.3	280	232
Chest depth	167.5	216	140
Neck circumference	305.6	332	288
Chest circumference at nipple	829.3	966	746
Chest circumference submammary	756	910	698
Arm circumference	241.7	269	208
Thigh circumference	506.7	566	455
Leg circumference	330.3	360	300
Breadth and length	173.6	181	165
Per cent breadth and length	7.4	11.6	4.3

* Girls who were 1½ standard deviations broader than average were classified as belonging in the extreme "Lateral" group. These data are to be compared with Table 2, which gives similar measurements for the nine girls classified as "Linear."

Body weight is recorded in kilograms; other measurements are recorded in millimeters.

Table 4.—Results of X-Ray Assessments of Growth of Skeleton, for Slender and Broad-Built Girls

A. Linear (Slender) Group

Case	Chronological Age	Hand* Assessment	Age Equivalent	Age Ratio
127	14.6	21	13.25	90.7
125	14.2	20	12.75	89.8
43	14.4	22	13.75	95.5
113	13.9	22	13.75	98.9
299	13	20	12.75	98.1
39	15.5	25	15.25	98.4
133	14.1	22	13.75	97.5
159	14.4	23	14.25	98.9
19	14.1	22	13.75	97.5
Average	14.2	21	13.25	96.1

B. Lateral (Broad-Built) Group

Case	Chronological Age	Hand* Assessment	Age Equivalent	Age Ratio
15	14.6	26	15.75	107
297	13.1	22	13.75	105
141	14.6	27	16.25	111
1	14.1	26	15.75	112
207	14.6	24	14.75	101
227	14.3	27	16.25	113
205	14.0	25	15.25	108
233	14.0	26	15.75	112
135	14.5	27	16.25	112
Average	14.2	25.5	15.53	109

C. Intermediate Group

	Averages for Ninety-three Girls
Chronological age	14.5
Wrist assessment	23.8
Age equivalent	14.5
Age ratio	100

* The x-ray assessments were made by Dr. Nancy Bayley.

computation of a convenient index of body build, and the selection of groups of individuals to exemplify the extremes of the distribution.

The normal sampling of girls at a given chronological age (*e. g.*, twelve years) shows a wide range of variation in each of the measures used. We have been especially interested in subsamples, selected from the extremes of the distribution with respect to body build. A classification into lateral (broad-built) or linear (slim) groups, based entirely on width-length indices,[9] has been used in selecting the subsamples. The measure employed is bi-iliac diameter divided by standing height. Girls who varied as much as 1.5 standard deviations from the mean in either direction were included in the extreme groups, used for a number of preliminary investigations.

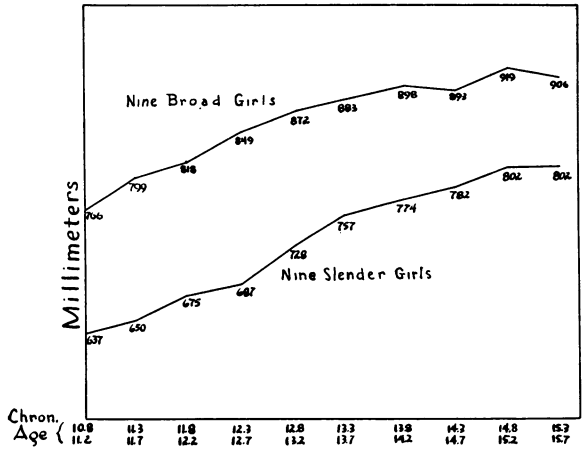

Chart 3.—Growth curves chest girth.

In Table 1 are given the means and standard deviations of anthropometric measurements of ninety-three twelve-year-old girls. These data are used as a general basis for comparison. Tables 2 and 3 show the same measurements for the linear-type and lateral-type girls, respectively, in the same series, and hence the three tables record the extent of variation in the normal sample, and the nature of the groups used to illustrate the extreme variates. Charts 1, 2, 3, and 4 are graphic representations of differences in body measurements between

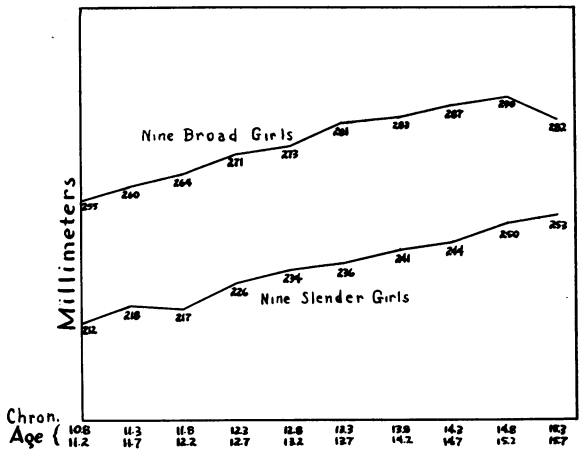

Chart 4.—Growth curves bi-iliac diameter.

linear and lateral groups of girls for a period of four years.

Using this lateral-linear classification, based entirely on width-length indices,[9] it is interesting to note that fifteen anthropometric measurements fall in line consistently year after year, with almost no overlapping. This is an indication of harmony and consistency, which supports the hypothesis that the two selected extreme groups differ in total body-build pattern, and not merely in one or two dimensions.

CLINICAL MEDICAL EXAMINATIONS

At the time of the regular physical examinations, observations were made of general health conditions, colds and other infections, posture, strength, muscular tone, and nutritional status. In addition, records were kept of handedness, eyedness, scapular type, and other conditions relating to development, coördination, and general health. Ratings were made of developmental conditions diagnostic of maturation, such as presence and amount of axillary and pubic hair, development of breasts and of subcutaneous tissue in other areas, and the time of establishment of catamenia. Photographs taken at these regular intervals furnish a permanent record of many of these facts, and of additional configurational factors difficult to describe other than by photographs.

Figures 2 and 3 are outline drawings of a linear type and a lateral type girl, respectively, showing the same girl at successive six-month intervals in each case. These figures portray aspects of growth characteristic of persons in the two classifications. Tracings were made of standardized photographs, to obtain the outlines, and the meanings of the various labels are as follows:

1. Height deviation range—percentage above or below average.
2. W/H index range—percentage broader or narrower than average.
3. Scapular type—CC (concave), CV (convex), and St. (straight).
4. Handedness—right or left.
5. Eyedness—right or left.
6. BMR range—highest to lowest.
7. Joint maturity x-ray—appraisal of ossification of the hand.

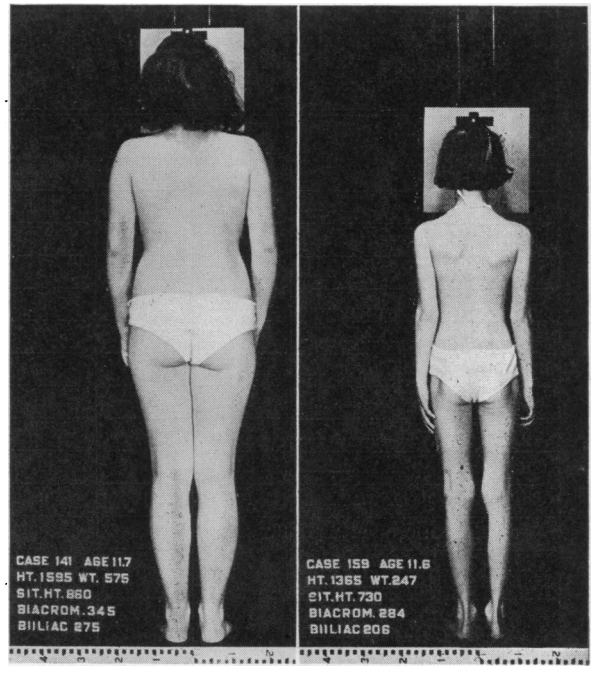

Figure 1.

Axillary and pubic hair, and size of breasts were rated as previously described.[1] The time of establishment of catamenia is indicated by a star on the figure. The five outline columns represent percentage increase over previous six months in bi-acromial diameter, bi-iliac diameter, height, stem length, and girth of calf, respectively.

The average age of appearance of catamenia in the broad-built group was 11.7 years, while the average age in the slender-built group will be over fourteen years. The exact average for this latter group cannot be calculated at present, because some of them have not yet menstruated.

There was very little growth in height in the broad-built girls after appearance of catamenia, while growth in height increased regularly in the slender girls of the same chronological age. Growth in diameters and girths slows up markedly in the broad-built girls during the same period of time that the slender girls start their adolescent spurt in growth.

Study of the results of these clinical medical examinations shows that some of the great variation in human growth at puberty is due to the mixture of the different types, one of which grows rapidly at age eleven to twelve years, and reaches full stature. The other type begins the adolescent spurt one to two years later, grows more slowly, and matures later.

In the present-day enthusiasm for establishing standards of growth and development, and for regimenting school children, the importance of individual differences is often overlooked, or inadequately considered. The general attitude that all persons are to be evaluated by reference to the same standards, when applied to physical and medical data, works an injustice on those individuals who vary from the average to a marked degree. In many individuals, growth follows a course quite

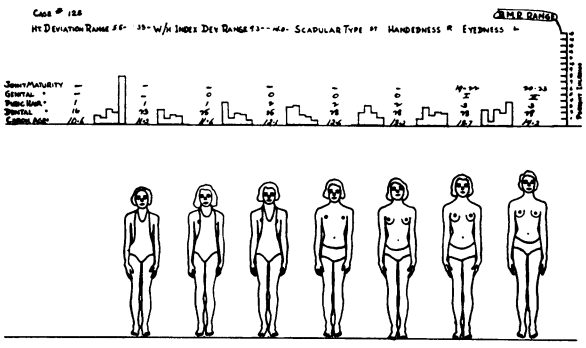

Figure 2.

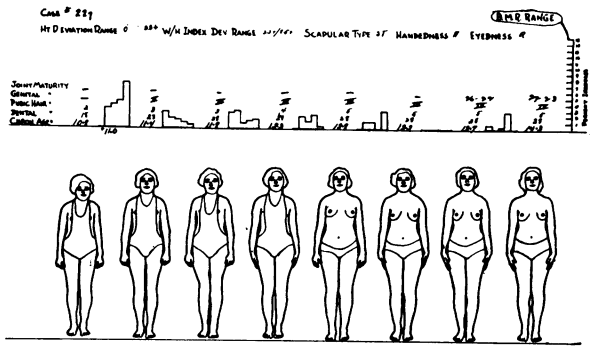

Figure 3.

unlike that of the average person, but entirely normal for the individuals concerned.

INTERRELATIONSHIPS

Figure 1 shows standardized photographs of a linear and a lateral girl, matched for chronological age. The slender-built girl lagged behind the broad-built one in ossification two and one-half years, and in establishment of catamenia four years. These photographs illustrate the sort of developmental difference associated with difference in body build.

Table 4 shows chronological age, assessment of bone development, age equivalent, and age ratio, for all of the very broad and very slender girls in this series, compared with the averages for the whole series. All of the lateral group of girls had accelerated bone development, and all of the linear group had retarded bone development.

Hence, in addition to individual divergencies from average, which might be due to acute diseases, there appears to be a body-build difference in ossification. The x-ray studies of our adolescent group show that ossification proceeded more rapidly in the broad-built than in the slender-built. In the latter group, epiphyseal ossification consistently lagged behind that in the broad-built group. The evidence for the two groups is shown in Table 4; the picture is consistently similar to that of the cases used in the illustrations of Figure 1.

SUMMARY AND CONCLUSIONS

As part of the larger study of adolescence being carried on at the Institute of Child Welfare, a longitudinal study of physical and physiological aspects of growth and development of one hundred girls has been included. Retests at six-month periods over a period of several years have included anthropometric measurements, clinical physical examinations, observations, x-rays, and the taking of serial photographs. The analysis of the cumulative records justifies the following conclusions:

1. Individual differences must be recognized in the assessment of growth. The important thing is the maintenance of an adequate rate of progress, and not the attainment of an absolute stature or size.

2. When body build was classified entirely on the basis of width-length index, study of extreme groups revealed interesting consistencies in other measurements, in relation to body build. In each of fifteen anthropometric measurements, wide differences were observed between broad and slender girls, with no overlapping at any point.

3. Study of the records indicates that physiologic development parallels rather closely anatomic development. Marked differences in rate of maturation were observed, as the broad-built girls matured at an earlier age than did the slender girls.

4. When x-ray methods were used to assess development by estimating anatomic age, a body-build difference in time and rate of ossification was demonstrated. On the wrist assessments of anatomical age from x-rays, broad-built girls had age equivalents greater than their chronological ages, and slender-built girls had age equivalents less than their chronological ages. The age ratios, when averaged, were 109 for the broad-built and 96.1 for the slender-built girls.

5. The data led to the conclusion that the mixture of groups of individuals heterogeneous with respect to body build accounts for some of the great variation in human growth at puberty, when observed in any ordinary unselected sampling.

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DISCUSSION

H. Lisser, M. D. (384 Post Street, San Francisco).—This study distinguishes, with great clarity, two widely different types of skeletal growth in *normal* adolescent girls—the "lateral" or broad-built group and the "linear" or

slim-slender group. Merely calling attention to broad and slender skeletal patterns would elicit little interest if it were not for the fairly consistent, associated distinctions involving the degree of osseous development or "bone-age" and the concomitant sexual age. These latter findings are of trenchant significance, for they emphasize, even in *normal* girls, the intimate inter-relationship between sexual maturity and termination of growth. Thus, if the menarche occurs for instance at twelve years of age, the "bone-age" will probably be nearer fifteen years, and longitudinal growth will practically cease when this girl reaches the age of fourteen. This study points out that this combination of events is most frequent in the broad-built type of girl who matures relatively early and, therefore, stops growing comparatively early. Contrariwise, the slender-type girl matures later, at fourteen or fifteen years of age; her "bone-age" is apt to be slightly retarded in comparison to her chronological age, and the onset of menstruation and fruition of secondary sex characteristics will be correspondingly delayed. Yet, both these extremes are fairly common and within reasonable limits may be considered normal.

The recognition of these two divergent types in *normal* girls, with accompanying differences in osseous and sexual development, leads to a consideration of these two types when exaggerated to a degree interpreted as *abnormal* or pathological. In addition to normally inherited, constitutional factors influencing skeletal patterns, attention must be paid to the dominating rôle of the endocrines in controlling growth and sexual development. Thus, a granulosa-cell tumor of an ovary producing precocious sexual maturity, with onset of menstruation during the first few years of life, will stimulate rapid skeletal growth at first, but with advanced ossification and premature closure of the epiphyses resulting in early cessation of growth. Similarly, an adrenal cortical tumor originating in a little girl causes a pseudo-sexual precocity, with early appearance of pubic hair, enlarged clitoris, accelerated skeletal growth and again advanced "bone-age" with eventual shortness. The skeletal set-up of such girls is apt to be "lateral," broad-built, or heavy, a pathological exaggeration of what the authors described in normal adolescent girls. Such girls at a chronological age of five years, may have a "bone-age" of twelve.

On the other hand, the antithesis of such precocious ripening is exemplified in preadolescent eunuchoidism, the clinical picture of which is typified by eunuchoid-tallness (not true gigantism), with disproportionally long extremities, slenderness, severe delay in appearance of secondary sex characteristics, very late onset of menstruation, if at all, and in unison, extreme retardation of ossification. This type of endocrinopathy would be illustrated by a girl of twenty-four years, with no mammary development, with very sparse pubic hair, who has not menstruated, with span greater than height and lower measurement far exceeding the upper, and with an osseous status of twelve years.

In the previous two paragraphs endocrinopathies have been described which illustrate extreme exaggeration of the two normal types defined by Drs. Pryor and Carter. The discussant has studied a considerable number of such patients, but so severe disturbances of endocrine function are uncommon. Manifestly, however, instances of milder deviation, between the extremes of normal and grossly abnormal, are to be expected, and are encountered quite frequently. Proper recognition and appropriate therapy can be extremely helpful.

It is to be emphasized, therefore, that the authors' careful observations in normal adolescent girls corroborate the important corelations, long known to endocrinologists in more outspoken form, between skeletal patterns, "bone-age," and the degree of sexual maturity. Broad-built girls mature early, and grow very little after thirteen years of age, whereas linear slender girls mature relatively late and, therefore, are still growing at sixteen. "Bone-age" estimations should be utilized more frequently in pediatric practice. The thyroid, pituitary, adrenals, and gonads have important influences in accelerating, delaying, or arresting both skeletal growth and sexual maturity.

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WILLIAM ANTHONY REILLY, M. D. (384 Post Street, San Francisco).—From Doctor Pryor's significant and interesting findings practitioners should recognize several helpful trends. These are: That there are individual differences in body-build (linear, lateral, and mixed); that it is incorrect to consider only a mean or an average for the growth factor of height, weight, epiphyseal age, pulse, blood pressure, basal metabolism rates, etc.—in place of means or averages we should always consider the limits of the range of findings; that there is a difference between chronological age and physiologic or anatomic age—the latter including maturity, bone-age, etc. Such proven facts help the practitioner allay the fears of family, teacher, and school nurse, concerning normal weight and the like. If one takes into consideration skeletal build (and especially the height-width index), the child very often is quite normal in weight.

I believe pediatricians, especially, are making more use of these findings. It will be practically helpful to practitioners when standards for basal metabolism can be computed on body-build better than at present.

Of personal interest to me is the finding that broad-built girls often have the following findings—they are mostly of European stock, with marked acceleration of bone-age, tall and obese, and some years premature physical and gonadal maturity. They have a definite tendency to a lowered basal metabolism. Physical measurements, examination of the genitalia, and glucose tolerance tests were uninformative. Tests for growth and sex hormones gave negative results. I have never been able to ascribe a definite physiological reason for these findings.

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H. E. THELANDER, M. D. (384 Post Street, San Francisco).—The recent tendency to study intensively the individual and his variation from the mean cannot be too highly commended. Problems arise in individuals and not in masses, and it is usually the extreme deviate who becomes a problem. Adolescence represents an age in which variations are most marked. A study like this will eventually be of great service, not only to the medical man but to the psychiatrist and the educator—in fact, to anyone dealing with children in this age group.

ROENTGEN THERAPY: SOME OF ITS COMPLICATIONS*

By RICHARD T. TAYLOR, M.D.
Los Angeles

DISCUSSION *by L. H. Garland, M. D., San Francisco; John D. Lawson, M. D., Sacramento; Wilbur Bailey, M. D., Los Angeles.*

IN this day of large roentgen dosages when the cry is on to more and bigger voltages, to more and more milliamperes and to more and huger roentgens, very little is said regarding the *bad* effects of increasing doses; and yet we all see them and fear them. Believing that a review of what one can see and feel in the patient undergoing treatment is a better exposition of our difficulties, especially if one uses the words of a master therapist, than a discussion of microscopic data, I beg leave to outline some points from Doctor Coutard's talk in Chicago last winter, wherein this subject received the best treatment I have ever heard.

MUCOUS MEMBRANES

If we have an individual who presents a cancer of the pharynx and we apply irradiation every day through two opposing fields, each about sixty square centimeters in size, for a dose of 4000 r in ten days, and if we examine the patient each day, we see on the irradiated mucous membrane a complete destruction of all epithelial cells, leaving the

* Read before the Radiology Section of the California Medical Association at the sixty-sixth annual session, Del Monte, May 2–6, 1937.